

Zoological Society's Insect-house during the past summer have been partially devoted during the winter months to the use of small reptiles and batrachians, for which they seem to be in every respect well adapted. Most of these animals, although shy and retiring in their habits, enjoy the warmth of the sun's rays and thrive excellently in their new habitations.

Amongst the batrachians thus exhibited are several species of gigantic size when compared with their puny representatives in this country, such as the Agua Toad (*Bufo agua*) of Brazil and the Ocellated Bladder-Frog (*Cystignathus ocellatus*) of Buenos Ayres. But by far the most remarkable of these forms in the series is the

Adorned Ceratophrys, or "Esquerzo" of the natives of the Argentine Republic—a large toad of brilliant colours and extraordinary form, of which a figure (Fig 16) is now given, taken from a water-colour sketch prepared by Mr. Ernest Griset.

The Esquerzo was discovered by Mr. Darwin during the celebrated voyage of H.M.S. *Beagle*, and first described by the late Prof. Bell in the "Zoology of the Voyage of the *Beagle*." This monster inhabits the pampas of Buenos Ayres, and is said to feed chiefly on its smaller brethren of the same class. Mr. Ernest William White, F.Z.S., to whom the Society is indebted for one of the two specimens now in the Gardens,



FIG. 16.—The Esquerzo, or Barking Toad.

specially mentions it in his lately-published "Cameos from the Silver-Land" as one of the characteristic forms of the grassy plains of the Argentine Republic. "In the damp grass," he says, may often be perceived the leering eyes and mottled black and green body of the huge Esquerzo (*Ceratophrys ornata*), whose gaping mouth crammed with the body of an unfortunate *sapo* (toad), and surmounted by threatening horns, inspires terror. This said Esquerzo bears an awfully spiteful character, and is credited with the deaths of many children. His appearance is certainly against him, but he is otherwise perfectly harmless."

The Esquerzo seems to thrive equally well on English

frogs as on the toads of Buenos Ayres, and does well in captivity. It is not, however, a very good object of exhibition, as, if left to its own devices, it hollows out a cavity to fit its body into the turf with which it is supplied, and leaves only the top of its head and projecting eyebrows barely visible. If harried out of its retreat for the examination of some curious visitor, it expands its body into almost a circular shape, and bites fiercely at any small object presented to it. At the same time it gives vent to its injured feelings in an angry whine, something like the snarl of a puppy, which has caused it to be known amongst the frequenters of the Gardens as the "Barking Toad."

#### NOTES

WE are glad to notice that a decided step has been taken towards the preservation of our ancient monuments. Sir John Lubbock has succeeded in getting the following resolution adopted in the House of Commons:—"That pending the introduction of a general measure dealing with the ancient monuments of the kingdom, and in order as far as possible to protect them from further injury, it is desirable that Her Majesty's Government should appoint one or more inspectors with authority to inspect and report upon such ancient monuments." Mr. Shaw-Lefevre, on the part of the Government, assented to the motion, and added that it was their intention to bring in a Bill dealing with the subject in which the hon. baronet took so much interest.

Thus Sir John Lubbock's determined perseverance in this important matter is likely at last to meet its reward.

IN deference to the strong feeling which evidently exists on the matter, the Zoological Society may be induced, if not too late, to reconsider the bargain they have made with Mr. Barnum for the disposal of their great African elephant, Jumbo, the universal pet of children. He has, we understand, been sold for 2000/-, but has shown so obstinate and touching a determination not to leave the Gardens which have been his home since a baby that it seems cruel to force him to do so. The general feeling is expressed in a letter which we print to-day, and during the last few days there have been numerous remonstrances on the subject in the press; one correspondent suggests that if

the Society is really in want of the money, the public would be only too glad to raise it to keep Jumbo. One reason given for parting with the animal is the uncertainty of his temper; but we doubt if there is any real ground for this excuse, and we hope it is not too late to prevent the children breaking their hearts for the loss of their favourite.

In vol. xxiii. p. 561, we gave an illustration of the new Etna Observatory, and stated that it would probably be completed by 1882. Signor V. Tedeschi writes from Catania to the *Daily News* that the Observatory has just been finished. Signor Tedeschi points out the exceptional advantages possessed by the Observatory from its lofty position for astronomical and spectroscopic observations. "These advantages," he states, "induced the Municipality of Catania, at whose expense the observatory was constructed, to aim at its being an international station, and so they added to the observatory three large bedrooms, a dining-room, and kitchen for the use of such foreign men of science as desire to remain there for some time, and the telescope is furnished with a movable iron tube, the length and aperture of which can be modified at pleasure, so that foreign astronomers can apply the instruments they bring with them. The observatory is built on a little eminence on the side of the central crater of Etna, a position which makes it almost certain that should a stream of lava issue on that side it would divide into two streams and flow harmlessly on each side of the little hill. The building consists of two storeys, the joint height of which is 9 metres, and the base of the edifice occupies a superficial area of 200 square metres. In each storey there is a large circular room surrounded by other chambers destined for different uses. In the centre of the circular room in the lower storey there is a solid pillar to support the great refractor. All the instruments, as well as a fine collection of seismographic and meteorological apparatus are in the upper storey, in the large circular room of which are the telescope and chronometrical apparatus. This room is roofed with a movable iron dome. The observatory on Etna is the highest building in Europe. The observatory on Vesuvius is 619 metres above the level of the sea, the Hospice of the Gotthardt 2075 metres, and that of St. Bernard 2491; while the Etna observatory is at a height of 2942 metres." This observatory will probably render invaluable service to astronomical science as well as to terrestrial physics.

NATAL, we are glad to learn, is going to have an observatory, as will be seen from the following extract from a Grahamstown paper:—"Through the generosity of three well-to-do colonists in Durban we are going to have an observatory at Natal at last. It seems that Mr. Gill, the Astronomer-Royal at the Cape, is now on a visit to the port, and noticing that Durban is a favourable site for observing the transit of Venus, he mentioned the circumstance to Mr. Henry Escombe, who at once offered to give a first-rate equatorial telescope, costing 450*l.* The Town Council granted a site for the observatory, and Mr. W. Randles and Mr. Greenacre, two Durban merchants, undertook to defray the cost of the building (300*l.* to 400*l.* between them)." A correspondent of the *Scotsman* commends this excellent example to the shipowners and landowners of Scotland, whose interests would be specially served by a well-equipped observatory on Ben Nevis.

NINE lectures on the Anatomy, Physiology, and Zoology of the Edentata will be delivered in the theatre of the Royal College of Surgeons, on Mondays, Wednesdays, and Fridays, at 4 o'clock, commencing on Monday, February 27, by Prof. W. H. Flower, LL.D., F.R.C.S. The following is a programme of the course:—General characters of the order: Family *Bradypodidae*—the Sloths; *Megatherium* and other great extinct Ground Sloths of America; Family *Myrmecophagidae*—the true Anteaters;

Family *Dasylopidae*—the Armadillos; *Glyptodon*—and other extinct Armadillo-like animals; Family *Manidae*—the Pangolins or Scaly Anteaters or Aard-varks; the extinct Edentata of the Old World; Classification of Edentata and relation to other groups.

IN connection with the International Electric Exhibition at the Crystal Palace, arrangements have been made with Prof. S. P. Thompson, of University College, Bristol, to give the following course of lectures:—1. Electric Currents—What are they? (February 22); 2. Electric Currents—How to make them by Steam? (March 1); 3. Electric Arc Lights (March 8); 4. Electric Incandescent Lamps (March 15), on each evening at 8 p.m. The lectures will be illustrated by diagrams in the magic lantern, by experiments on a large scale, and by experiments in the magic lantern. This is a praiseworthy step on the part of the directors, and we hope it will meet with encouragement.

AT the meeting of the Essex Field Club, to be held at Buckhurst Hill, next Saturday, February 25, the desirability of directing public attention to the pressing necessity which exists that some means should be adopted for the protection of our native animals and birds from wanton destruction by gamekeepers and others, will be brought before the Club by Sir Fowell Buxton, Bart. (Verderer of Epping Forest). Zoologists and lovers of Nature generally, whether Members of the Society or not, are earnestly requested to attend, and take part in the discussion.

ONE of the most recent additions to Chinese literature, according to the *China Review*, is a translation of Gray's well-known work on Anatomy. The translator, the late Dr. Osgood, is said to have succeeded in the task of giving Chinese names to the multifarious and minute structures which constitute the human body. The difficulty of this will be obvious, when it is remembered that the Chinese know hardly anything of anatomy, or of the functions of the various organs of the body. The only work up to this in Chinese on the subject was a very elementary one, published nearly twenty years ago, by a European physician.

A CHAIN of meridian distances, extending from Vladivostok to Madras, has been telegraphically measured during the past year by Lieut.-Commanders Green and Davis, and Lieut. Norris of the U.S. Navy. The stations occupied and determined were Vladivostok, Nagasaki, Yokohama, Shanghai, Amoy, Hong-kong, Manila, Saigon, Singapore, and Madras. The exact longitudes of the two terminal stations had been previously established by Russian and English officers, but the positions of the intermediate stations from which nearly all the longitudes of China and Japan have been chronometrically measured have always been seriously in doubt.

ATTENTION continues to be bestowed on the search for new elements, and the classification of those which have been recently discovered. According to Phipson (*Compt. rendus*, xciii. 317), a specimen of zinc pigment examined by him contained about 4 per cent. of a new metal, to which, because of the action of light upon its salts, he gives the name *Actinium*. Mendeleeff (*Berichte*, xiv. 2821) shows that the recently discovered cerite metal Ytterbium finds its natural place in his scheme of classifying the elements according to their atomic weights. Two new chlorides of Gallium are described by L. de Boisbaudran (*Compt. rend.*, xciii. 294), and determinations of the density of the vapour of gallic chloride have confirmed the number 69·9 as the atomic weight of Gallium.

CHEMISTS are now paying much attention to the study of chemical changes, and they are beginning to venture on a few generalisations. Several Russian chemists have recently made important advances, notably Kajander, who considers the velocity of the changes which proceed when metals are dissolved

by various acids (*Berichte*, xiv. 2666), and finds that the rate of solution varies, according to the strength of acid, in the same way as the electric conductivity of the acid varies. Menschutkin (*J. Pract. Chem.*, xxiv. 49) continues his researches into the rate of etherification of various alcohols, and succeeds in tracing definite connections between this rate and the "molecular structure" of the various alcohols examined. Tribe (*Chem. News*, xliv. 185) attempts to measure the relative affinities between the constituents of electrolytes, by determining the magnitudes of the spaces between the boundaries of electro-deposits on metallic plates.

No. 2, Segundo anno (1 Feb. 1882), of the *Revista da Sociedade de Instrução do Porto* (published at Oporto) commences with the first instalment of a "Catalogue des Insectes du Portugal," by Prof. M. P. d'Oliveira of Coimbra, printed in French. The somewhat lengthy introduction brings to light the existence in Portugal of more entomologists than most of us suspected, according to the list of persons thanked by the author for the assistance they have rendered him. The *Coleoptera* are commenced, but do not at present extend beyond the genus *Omophron* in the *Carabidae*.

THE temperature of the southern hemisphere has lately been investigated by Dr. Hann with the aid of recent observations of temperature in high southern latitudes, especially those made during the Venus transit in 1874. For mean temperature of the whole hemisphere he obtains  $15^{\circ}4$  C., and as that of the northern hemisphere was estimated by Ferrel to be  $15^{\circ}3$  C., it is very probable that both hemispheres have the same mean temperature. Dr. Hann, however, also shows that between  $40^{\circ}$  and  $45^{\circ}$  south latitude the southern hemisphere becomes warmer than the northern in the same latitude, and that a difference between the two persists at least to the confines of the hypothetical antarctic continent. The results of the projected antarctic scientific expedition this year, which will include a whole year's meteorological and magnetic observations in high latitudes, will do much, doubtless, to clear up the subject of temperatures. Dr. Hann urges the usefulness of a careful determination of ground-temperatures on islands (McDonald's Islands, Auckland, Maquarie, South Orkney, &c.).

PROF. HEIM, of Zurich, has visited Fettan, the village in the Grisons which is being swallowed up by the ancient moraine on which it is built. He ascribes the phenomenon to the movement of underground waters, and considers that the perils may be averted by certain engineering operations, which will probably be executed under his superintendence.

PROF. NAUDIN has observed a lowering of the level of the Mediterranean at Antibes (Alpes maritimes) which amounts to 30 centimetres. He believes the reason to be the rising of the coast through volcanic influences. The inhabitants of the coast ascribe the phenomenon to the recent prolonged dry weather. Dr. Faye of Paris has also studied the subject, and according to his opinion it is the recent high atmospheric pressure which causes the recession of the sea in that locality.

DR. MAX BUCHNER, the explorer of the Lunda district, West Africa, has reported on his recent journey to the Berlin "Gesellschaft für Erdkunde." On December 10, 1878, he had started on his journey from St. Paul de Loanda to Malange (lat.  $9^{\circ} 32'$  S., long.  $16^{\circ} 38'$  E.). There he waited for the dry season, and by the end of July, 1879, he continued his journey with a caravan numbering 160 people. Without much trouble he passed through the land of the Songo, crossed the Quango and numerous other rivers, and penetrated to the residence of the Kioko chief, Mona Kissenge, who took him to be a merchant and wanted to stop him. Dr. Buchner managed to overcome all hindrance, and reached Kabongo (lat.

$9^{\circ} 30'$  S., long.  $21^{\circ}$  E.), entering Musumba, the residence of Muati Yambo, the Lunda chief, on December 11, 1879. Musumba numbers 2000 inhabitants, and is the Eldorado of the slave trade. Muati Yambo and Queen Lukukesse, who reigns independently, received Dr. Buchner in solemn audience, but as the chief also believed him to be a merchant, he did not permit the traveller to proceed further into districts whence he himself purchases slaves and ivory, in which he does a large trade. Dr. Buchner remained at Musumba for six months and then pretended to return. Near the Kassai River he turned to the north in order to penetrate into the unknown districts by the land of the Tukungo. This attempt however failed. Two other attempts to reach Kilua (Muata Kumpana's residence) also failed through the positive resistance of the inhabitants, and the mutiny of his guides and carriers. Thus he was compelled to return to Malansh.

THE deaths are announced of M. Antoine Alexandre Brutus Bussy, member of the Academy of Sciences, an eminent chemist and physicist, at Marseilles, on February 4, aged eighty-eight; of Dr. Franz Schlegel, director of the Breslau Zoological Gardens, on February 7; of Frederick Warrington of Tripoli, who for over fifty years hospitably received and liberally assisted all African travellers who started from Tripoli for the interior, on January 26, aged seventy-four; of Herr Blasius Kleciak, a "Commissar" on the Dalmatian island of Lesina, and well-known as a conchologist, on January 12 last; of Dr. Simon Syrski, Professor of Zoology at Lemberg University, an eminent ichthyologist, on January 14, aged fifty-one; of Dr. F. J. Stamkart, formerly Professor at the Polytechnical School of Delft, Holland, an eminent mathematician, who died recently at Delft, aged seventy-seven; of M. Felix Billet, Dean of Dijon University, corresponding member of the Academy of Sciences, and author of numerous physical works and treatises, who died at Dijon on January 29, aged seventy-four.

A COMPANY has been formed at Palermo with the object of constructing a railway to the summit of Mount Etna, in imitation of the Vesuvius Railway.

THE International Polar Commission has issued the first number of a special publication, edited by the President, Dr. Wild, to appear in regular numbers, for the purpose of insuring the rapid and continuous dissemination of intelligence relating to the International Polar Expedition. This number gives a sketch of the history of the scheme, the programme of observation, and a brief statement of what has been done.

THE German Government has appointed a Commission consisting of Prof. Neumayer, Capt. von Schleinitz, Drs. Nachtigal, Dörgens, and Ernst Hermann, with the object of making the necessary preparations for erecting the German Meteorological station in the North Polar Region in conjunction with the other States participating in the International Polar Research recently planned. The Commission will meet at Hamburg during the present month.

PREPARATIONS for a North Polar Expedition which is to start during the present year are being actively made in Holland. The lead is taken by Prof. Buys Ballot of Utrecht. The Second Chamber has granted a subsidy of 30,000 florins, and a committee has been formed at Utrecht which intends to raise the additional funds that are necessary by means of public subscriptions.

THE Russian Geographical Society have resolved to fit out an exploring expedition to Novaya Zemlya, and to give the command to Andreiff.

THE first annual general meeting of the London Sanitary Protection Association is fixed for Saturday next. Prof. Huxley and Prof. Fleeming Jenkin will speak on the progress of the

Association, also Dr. Acland, Dr. Andrew Clark, Dr. Lauder Brunton, &c. It seems that of the 192 members of the Association 22 are medical men.

WE see from a report in the *British Guiana Colonist*, that the Museum in Georgetown, belonging to the Royal Agricultural and Commercial Society, is making excellent progress. Mr. Im Thurn, who has already done good work for science in the Colony, has returned to take charge of the Museum, and the reforms he proposes to introduce, with the approval of the Society, promise to make the Museum one of real scientific value, as well as of practical importance in connection with the development of the resources and industry of the Colony. Mr. Im Thurn is authorised by the Society to bring out a skilled German taxidermist, so that in time the Museum will probably have a valuable collection of birds.

THE Italian Government has published some interesting facts relating to the state of the public instruction in that country. The recent law on primary schools has been applied to 7533 communes of the 8276 existing in the Peninsula and surrounding islands. The number of public teachers in these schools is 41,000, viz. 20,700 males and 20,300 females. Out of a population of 26,801,194 the pupils are 1,048,000 males and 853,429 females, for a yearly expense of 31,000,000 francs—26,000,000 for wages and 5,000,000 for matériel. There are besides 7422 private primary schools with 7422 male and 4444 female teachers, but with 92,228 female and only 63,000 male pupils. There are also in the kingdom 11,161 male evening schools for adults and 472 female, the first with 439,624 pupils, and the other with 16,063. Females largely preponderate in Sunday schools; there are only 592 schools and 21,914 pupils for male Sunday instruction, and 5979 with 191,245 for females.

EARTHQUAKES in the northern alluvial districts of Europe are certainly of rare occurrence. Reports from many localities, however, prove that an earthquake was observed in North Schleswig and South Jutland on Jan. 14, between 10 and 11 p.m. The phenomenon was observed at Hadersleben, Kolding, Klitland, Ringkjöbing, &c. Early in January numerous shocks were observed upon the island of Chios. The western part of the island continues sinking deeper and deeper, so that its disappearance below sea level is shortly expected.

M. UJFALVY has returned from his journey to the Western Himalaya district, undertaken under the auspices of the French Government. This was the fourth scientific expedition undertaken by M. Ujfaly. He again brings large ethnographical collections, also numerous anthropological specimens, skulls, samples of hair, and measurements.

FROM the programme of the Second German "Geographentag," to be held in Halle on April 12-14, an interesting meeting may be expected. The papers which are to be read are all on subjects of scientific interest, and afford one more proof of the highly scientific conception which Germans have of Geography.

THE "Handbook of Cinchona Culture," by Karl Wessel van Gorkom, formerly Director of the Government Cinchona Plantations in Java, has been translated by Mr. B. D. Jackson, Botanical Secretary of the Linnean Society of London, and will be shortly published by Trübner and Co.

CONFLAGRATIONS have at all times been the plague of Japanese towns. It has been said that Tokio, the capital of Japan, is rebuilt once in every seven years. During the winter of 1880-81 it was calculated that three-tenths of the city was destroyed by fire. Almost the whole commercial quarter, situated in the heart of the town, disappeared, leaving nothing but blackened

ruins behind. Each winter a tale of similar desolation comes from almost every town in Japan. Various modes of meeting or preventing calamities of this description have been suggested. A system of national insurance has been proposed; the arrangement of the towns in sections, each surrounded by a large wall, which would confine fires to a single quarter, as in Peking, was mooted last year, but as yet nothing has been done. Expense has generally been the chief obstacle; but a paper in the last (the 25th) number of the *Mittheilungen der deutschen Gesellschaft für Natur und Völkerkunde Ostasiens*, by Dr. O. Korschelt, a chemist in the employ of the Japanese Government, suggests an economical, and apparently very practicable, way of meeting the difficulty. The paper deals with Japanese soil as a natural cement material. He shows that the usual soils on the plains of Japan, derived from volcanic tufa, closely resemble *puzulana* and *trass* in composition, and form the basis of an excellent cement. Chemical and mechanical analyses of several of these tufa soils are given; their specific gravity is less than that of any other soils except those containing very large amounts of vegetable matter. Mixed with one-sixth their volume of lime, these soils form excellent cement for building purposes, and the writer points out that by using such materials the Japanese could substitute stone houses for wooden ones in nearly all their provinces in a very simple and economical manner, and thus save to a very large extent the enormous annual waste of substance which occurs through fires. There is no lack of this material; the higher lands of the city of Jedo stand on beds twenty feet in thickness. Referring to the agricultural relations of these soils Dr. Korschelt coincides in the view previously brought forward by Mr. Kinch, that these soils are not by nature chemically rich, at all events in their mineral constituents, but that owing to their physical properties, which in turn are dependent mainly on the large amount of easily decomposable zeolitic silicates they contain, are most admirably adapted to the system of agriculture pursued by the people.

AMONG the papers in the last number of the *Mittheilungen* is one by Dr. Naumann, on the Trias formation in Northern Japan; by Dr. Döderlein on Japanese marine snakes, and the analysis of a fragment of meteorite by Dr. Korschelt.

THE Perthshire Natural History Society have issued Part I of the first volume of their *Proceedings*. It is neatly got up and contains abstracts of the various papers read at the meetings, 1880-81, and an account of the excursions for which the Society is so favourably situated.

THE *Ausland* states that M. Raffray, the French Vice-Consul at Massowah, discovered in the Land of the Gallas in the mountains of Oebul (Sabul?), at ten different places, rocks of which the interior was excavated and transformed into places of worship. He is of opinion that these rocky chapels date from the fifth century.

THE 200th anniversary of the birth of Johann Friedrich Boettiger, the inventor of porcelain, was celebrated at his birthplace, Schleiz (Germany), on February 4. The Royal porcelain factory of Meissen sent an artistically designed votive tablet to the civic authorities of Schleiz, which was fixed to the "Rathhaus" of that town on that day.

THE additions to the Zoological Society's Gardens during the past week include a Mule Deer (*Cervus macrotis* ♀) from North America, presented by Judge Caton; a Bauer's Parrakeet (*Platycercus zonarius*) from Australia, presented by Mr. S. Draper; a Common Buzzard (*Buteo vulgaris*), British, presented by Lord Walsingham, F.Z.S.; a Common Raven (*Corvus corax*) from Scotland, presented by Sir George Leith Buchanan, Bart.; an African Elephant (*Elephas africanus* ♂) from Africa, deposited; two Grey headed Love Birds (*Agapornis cana* ♂ ♀) from

Madagascar, a Common Coot (*Fulica atra*), British, a Blaubok (*Cephalophorus pygmaeus*) from South Africa, three Pluto Monkeys (*Cercopithecus pluto*) from West Africa, purchased; an Axis Deer (*Cervus axis* ♂), born in the Gardens.

#### THE INFLUENCE OF MATHEMATICS ON THE PROGRESS OF PHYSICS<sup>1</sup>

**I**N discussing the value of a given study, a lecturer is by common consent allowed—sometimes even in private duty bound—to exaggerate the importance of his subject, and to present it to his audience enlarged, as it were, through the magnifying power of a projecting lens, so that the details with which he has necessarily to deal may be brought into more prominent view. In an introductory lecture such as it is my duty to give to-day, the speaker need the less feel any scruples in following the usual custom, as different subjects are treated in successive years, and the hearer may, after the lapse of a short cycle, strike a pretty fair balance between the various branches which have successively been brought before him. But although I might have felt tempted to-day to insist on the advantages of Applied Mathematics as a separate subject not only worthy of study, but second to none in interest and importance, and though I feel no doubt you would have accorded to me the indulgence which everybody requires who endeavours to lay an abnormal stress on the merits of a single branch of human knowledge, I prefer to found the claims of the subject which I have the honour to represent in this college, not so much on its intrinsic value as on the influence it has had on the progress of other sciences. For no subject can stand by itself, and the utility of each must be measured by the part it takes in the play of the acting and reacting forces which weave together all sciences into a common web.

The growing importance of mathematics as an aid to the study of all sciences is daily becoming more apparent, and it may indeed be questioned whether at the present time we can speak of physics as apart from applied mathematics. Riemann's opinion that a *science* of physics only exists since the invention of differential equations is intelligible; but however close the connection between physics and mathematics may be or may become, their growth in the earlier stages has been altogether independent. Galileo may be said to have been the founder of mathematical physics, and amongst his successors have been many who showed a greater inclination towards pure mathematics than towards physics proper. On the other hand, we can trace back the ancestry of our experimental physicist and that of our modern popular books on science to the Middle Ages, where we reach J. Baptista Porta and his books on natural magic. Even eighty years ago the fullest account of the state of experimental science was to be found in "Wiegler's Natürliche Magie," a book of twenty volumes, in which scientific experiments and conjurers' tricks are alternately described. But since the beginning of this century the importance of the mathematical treatment of purely physical subjects has steadily grown, and fifty years ago the two sciences were already sufficiently united to induce the founders of the British Association to join them together into one section. From that time until the present year, when the mass of work necessitated a temporary separation, the experimentalist and the pure mathematician could be seen at the annual meetings listening, or at least appearing to listen, to each other's investigations, and the influence which men of science on these occasions had on each other may be taken to represent roughly the mutual influence of the two sciences themselves; it was substantial, though in great part unconscious. I could not attempt to-day to give you a complete historical survey of the effect which the contact—one might often say the collision—of the two sciences had on the progress of each; even that part of the subject which I have chosen for special consideration is too vast to be successfully confined within the limits of a single lecture, and an incomplete sketch is all I can offer.

The influence of mathematical investigations on physical theories is not restricted to any single stage, but makes itself apparent throughout the whole course of their evolution. Before a theory is even started, the mathematician is often necessary to prepare its way. He has to classify complicated facts in a systematic manner, and working backwards from the phenomena

presented by nature, he endeavours to find out which of them are necessary consequences of others, and which of them require independent hypotheses for their explanation. It is in this way that the works of Poisson, Green, Gauss, and of all those who have followed in their footsteps, may be said to have laid the foundation of the theory of magnetism and electricity, although we do not yet as possess any physical notions as to the causes of these phenomena. The true power of mathematics, however, comes into play only when the physical inventor has done his work, and has formed distinct materialistic conceptions which allow themselves to be expressed by mathematical symbols. It is then that the consequences of the theory are to be worked out and tested by experiment. In order to be convinced of the truth of any hypothesis, the scientific world wants quantitative experiments. Numbers form the connecting link between theory and verification, and they always imply mathematical formulae, however simple these may be. Often two rival theories are on their trial and the mathematician is supposed to find out where their conclusions differ and where crucial experiments are most likely to decide definitely between them. It is remarkable, however, how much more often physical or even metaphysical considerations have decided between two theories than arguments derived from mathematical reasoning. So-called crucial experiments, as a rule, come either too early or too late. Sir Humphry Davy's experiment was absolutely conclusive against the corpuscular theory of heat, but scientific ideas were not ripe yet for the discovery, and his experiment had no marked effect on the progress of science. The crucial experiment here did not involve any mathematical deductions; it is otherwise with that which might have decided between the two theories of light. According to the corpuscular theory, light travels more quickly in water than in air; according to the undulatory theory, the passage through water is the slower, and this distinction is founded on the necessity to account mathematically for the laws of refraction. But when Foucault actually made the experiment, and gave a death-blow to the corpuscular theory, that theory was already dead. There was then only one scientific man of note left who still viewed the undulatory theory with suspicion, and his suspicions were not allayed by the crucial experiment. But if mathematical deductions have not decided as often as they might have done between two rival theories, they have constantly strengthened and confirmed our belief in physical hypotheses by inventing new cases which might test the theory, and which might, if experiment supported the mathematical deduction, establish it on a yet firmer basis.

The most important of all the functions of mathematical physics, however, and perhaps the only one through which mathematics has had an unmitigated beneficial influence on the progress of physics is derived from its power to work out to their last consequences the assumptions and hypotheses of the experimentalist. All our theories are necessarily incomplete, for they must be general in order to avoid insurmountable difficulties. It is for the mathematician to find out how far experimental confirmation can be pushed, and where a new hypothesis is necessary. Facts apparently unconnected are found to have their origin in a common source, and often only a mathematician can trace their connection. It is here that the pure experimentalist most often fails. A new experiment gives results to him unexpected, and he is tempted to invent a new theory to account for a fact which may only be a remote consequence of a long-established truth. Many examples might be given to show how mathematics often finds a connection unsuspected by the pure experimentalist, but one may be sufficient. A ray of light passing through heavy glass placed in a magnetic field, in the direction of the lines of force, is doubly refracted as it comes out. To none but a mathematician is it clear that this is only a direct consequence of Faraday's discovery that the magnet turns the plane of polarisation of the ray on its passage through the glass. Happily this fact was first worked out theoretically; had it been otherwise, we should have heard much of the power of the magnet to produce double refraction.

In addition to the many services actually rendered by mathematical treatment, the mere attempt to put physical theories into a form fit for such a treatment has often been invaluable in clearing the theory of all unnecessary appendages and presenting it in the simple purity which may bring its hidden failings to light, or may suggest valuable generalisations. Instead of dealing, however, in a general manner with the various ways in which mathematics have been useful in the prosecution of physical investigations, it will be better to give a short account of the growth of

<sup>1</sup> A Lecture introductory to the Session 1881-82 of Owens College, Manchester, by Arthur Schuster, Ph.D., F.R.S., Professor of Applied Mathematics.